WHAT IS CLAIMED IS:

1.   A matrix coil for generating a variable magnetic field, comprising:

a plurality of loops arranged in a series so as to have a substantially common axis, each of the plurality of loops being segmented into at least one arc-shaped segment;

a variable current source for each of the arc-shaped segments; and

a controller configured to selectively vary an amount of current provided to each of the arc-shaped segments by the variable current sources so as to achieve a variable base field, one or more variable gradient fields, and one or more variable second order shim fields.

2.   The matrix coil of claim 1, wherein arc-shaped segments in consecutive loops are offset in a radial direction from one another.

3.   The matrix coil of claim 1, wherein the current source comprises a multi-channel amplifier, each channel of the multi-channel amplifier corresponding to the current source for an individual arc-shaped segment.

4.   The matrix coil of claim 1,

wherein at least two arc-shaped segments in different loops are connected in series, and

wherein a single current source supplies current to the series connected arc-shaped segments.

5.   The matrix coil of claim 1, further comprising a current lead coupling each current source to a respective arc-shaped segment, the current leads being substantially parallel to the common axis.

6.   The matrix coil of claim 5, wherein the current leads have a sufficient thickness to limit joule heat generated therein to a value less than about 10W.

7.   The matrix coil of claim 1, further comprising an array of current elements connected by current leads substantially parallel to the common axis.

8.   The matrix coil of claim 1, wherein a target field for an imaging region of interest is achieved by selectively varying the amount of current provided to each of the arc-shaped segments in accordance with a discrete approximation of a gradient current density stream function.

9.   The matrix coil of claim 8, wherein the target field is achieved by selectively varying the amount of current provided to each of N arc-shaped segments in accordance with the following equation:

$$B_z(r_m) = \frac{\mu}{4\pi} \sum\nolimits_{n=1}^{N} I_n \oint \frac{d_s \left[\varphi \bullet \left(r_n^{\cdot} - r_m \right) \right]_z}{\left| r_n^{\cdot} - r_m \right|^3}$$

where r_m are the mth sample point in the target field, m being an integer
        greater than 1, and

where $r_n^{\cdot}$ are position current elements ds_n along the nth arc of the N arc-
        shaped segments, N being an integer greater than 1.

10.   The matrix coil of claim 9, wherein the variable second order shim field(s) is achieved by selectively varying the amount of current provided to each of the arc-shaped segments in accordance with the following equations:

$$I_q = \frac{4\pi}{\mu} \sum_q \sum_m \left(A^T{}_{qm} A_{mn}\right)^{-1} A_{nm}{}^T Bz_m$$

$$A_{mn} = \oint \frac{ds\left[\varphi \circ \left(r_n^{\cdot} - r_m\right)\right]_z}{\left|r_n^{\cdot} - r_m\right|^3}$$

11.   The matrix coil of claim 1, wherein the plurality of loops are spaced apart at a substantially equal distance along the common axis.

12.   The matrix coil of claim 1, wherein end loops of the plurality of loops include more conductive material than a middle loop of the plurality of loops.

13.   The matrix coil of claim 1, wherein the controller includes a look-up table listing the amount of current provided to each of the plurality of loops to achieve a target field for an imaging region of interest.

14.   The matrix coil of claim 1, wherein the matrix coil includes at least 32 loops, each of the at least 32 loops being segmented into at least 8 arc-shaped segments.

15.   The matrix coil of claim 1, wherein the plurality of loops are arranged about a substantially cylinder substrate.

16.   The matrix coil of claim 15, wherein the substantially cylinder substrate has a diameter of at least 70 cm and a length of at least 200 cm.

17. The matrix coil of claim 1, wherein the plurality of loops are potted in epoxy with a fiberglass reinforcing structure.

18. A magnetic resonance imaging device including the matrix coil of claim 1.

19. A method of generating a variable magnetic field, comprising:

supplying a current to each of a plurality of arc-shaped segments within each of a plurality of loops, the plurality of loops being arranged in a series so as to have a substantially common axis; and

selectively varying the supplied current provided to each of the plurality of arc-shaped segments to achieve a variable base field, one or more variable gradient fields, and one or more variable second order shim fields.

20. The method of claim 19, further comprising:

supplying a current to an array of current elements connected by current leads substantially parallel to the common axis; and

selectively varying the supplied current provided to the array of current elements to achieve the variable base field, one or more variable gradient fields, and one or more variable second order shim fields.

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21. The method of claim 19, further comprising:

retrieving target current amounts for each of a plurality of arc-shaped segments from a look-up table based on a desired base field, one or more variable gradient fields, and one or more variable second order shim fields.

22. The method of claim 19, further comprising:

calculating target current amounts for each of the plurality of arc-shaped segments to achieve a target field for an imaging region of interest in accordance with the following equation:

$$B_z(r_m) = \frac{\mu}{4\pi} \sum_{n=1}^{N} I_n \oint \frac{ds\left[\varphi \circ \left(r_n^{\cdot} - r_m\right)\right]_z}{\left|r_n^{\cdot} - r_m\right|^3}$$

where r_m are the mth sample point in the target field, m being an integer greater than 1, and

where $r_n^{\cdot}$ are position current elements ds_n along the nth arc of the N arc-shaped segments, N being an integer greater than 1.

23. The method of claim 22, further comprising:

calculating target current amounts for each of the plurality of arc-shaped segments to achieve the variable second order shim field(s) in accordance with the following equations:

$$I_q = \frac{4\pi}{\mu} \sum_q \sum_m \left(A^T_{qm} A_{mn}\right)^{-1} A_{nm}^{\ T} Bz_m$$

$$A_{mn} = \oint \frac{ds\left[\varphi \circ \left(r_n^{\cdot} - r_m\right)\right]_z}{\left|r_n^{\cdot} - r_m\right|^3}$$

24. A magnetic resonance imaging device, comprising:

means for generating a variable base field, one or more variable gradient fields, and one or more variable second order shim fields;

means for supplying a current to the means for generating so as to achieve a target field for an imaging region of interest; and

means for determining a required current to achieve the target field for the imaging region of interest.